NASA Learning Technologies

Experiential Platform – *ExP*
Overview and Requirements Specification

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Preface

This document describes the NASA Learning Technologies ExP initiative for science education software. It presents an overview of the initiative and defines ExP goals and requirements. Review and comment by all are welcome, and at any time. Please address comments or questions to Patrick.J.Hogan@nasa.gov.

Several terms used within this specification are defined in detail in Section 4. First use of these terms is highlighted in bold type.

1 ExP Overview

ExP is NASA's initiative to focus many of its educational software efforts on long-lived, synergistic and on-line community based programs. This shift in focus is intended to increase the reach of NASA's science education efforts and to better meet the modern needs of science educators and students. Rather than developing many small, independent education-technology programs, ExP provides several large programs that attract and support active communities of science and technology providers, curriculum developers, teachers and students.

ExP uses its large audience to provide an attractive platform for educational technology and curriculum developers to target and to rally around. ExP gives these contributors greater visibility and their efforts longer reach. It makes their work less time-consuming and likely to make a more significant difference in a student's science education. It expands their impact.

ExP's foundation is a collection of software **applications** for learning science, mathematics, engineering and technology. These applications – software programs that students interact with, as they do a video game – are supported with tailored educational **activities** and timely science data, much of which is obtained directly from NASA data feeds. Applications can be extended after installation with new data, additional capabilities and fresh activities. ExP, itself, can be extended with new applications. On-line communities will form around these applications and are expected to keep them active, timely and growing.

Educators and scientists are able to extend ExP activities and application data themselves; no software programming is required. Science educators can focus on adding science content, not software. This is a fundamental requirement of ExP.

The most essential characteristic of ExP applications is that they provide an open setting that students can freely explore. Students are delivered into the cosmos, dropped onto a planet, injected into a body, or zapped into an atom. Their motion from then on is self determined: they can go anywhere, look at anything, climb over the scenery. Initially they are guided by activities and taught how to maneuver, but this merely gives them the tools to explore on their own, to form and answer their own questions. This is a tall order for a software application, but it's what many of today's computer games do, and is already available in candidate ExP applications.

ExP also gives software developers support for developing, packaging and releasing their applications, and for releasing subsequent updates. It contains **middleware** for commonly needed features such as 3D rendering, data gathering, and collaboration. It provides tools and software to equip applications for accessibility by those with disabilities. It offers a framework to support them.

Activities are an indispensable part of ExP. Guided inquiries presented in activities introduce students to the curricula and the applications. They focus students on particular learning goals, while also teaching them how to use the application to explore outside an activity, as their tool for investigation, inquiry and discovery. ExP offers many examples as models for new activities, and it provides guidelines for ensuring that activities meet standards for curricula, pedagogy, and applicability to organizational and government education goals, including federal and state standards.

All of ExP is available to the public. ExP is free to use, with the exception of a few outstanding but inexpensive commercial applications that can be licensed separately if desired. No commercial ExP software is required for use of the bulk of ExP.

A premise of ExP is that active, on-line communities are necessary to maintain, enhance and support useful software and thereby keep it valuable. The commercial and **open-source** software industries have taught us that software cost does not necessarily relate to software quality or value. Much of the best software today is open-source and free to use, and this trend is growing. The successful software efforts are those with active communities of developers, enhancers and users. By careful software selection and design – in many cases by adopting existing successful open-source efforts – ExP gathers the needed educational and development constituencies around NASA educational applications and supporting software.

ExP welcomes commercial software participation as long as that software meets the ExP requirements. It must be extensible in all ways by people other than the legal owners, and the work of these others must be unencumbered by fees or distribution constraints. The commercial software must be unique in its role in ExP. Its cost must be very low and appropriate for schools and home users. All ExP components, whether open or commercial, must meet the same requirements.

ExP is meant to last and live indefinitely. It will continually evolve to meet new needs and to take advantage of newly accessible technology. The NASA Learning Technologies Office will manage ExP and move it forward through targeted investment in directly commissioned projects and competitively awarded grants.

1.1 What's In ExP

ExP provides three general sets of materials:

- Software applications that students use to follow activities or explore independently.
- Activities guiding students through the applications and directing their study.
- Software components and infrastructure to aid development of ExP applications.

1.2 ExP Applications

ExP software applications address the five NASA enterprises:

- Aerospace Technology
- Biological and Physical Research
- Earth Science
- Human Exploration and Development of Space
- Space Science

Each ExP application provides education in at least one of these areas, and frequently several. As ExP evolves it will seek to balance its coverage of these enterprises, but will remain opportunistic in incorporating compelling science education applications as they are newly conceived by the NASA community and the public domain. The NASA Enterprise education teams review and nominate ExP applications.

Initial ExP applications – those incorporated in year 2003 – address all but the Human Exploration and Development of Space enterprise. The applications are:

- For Space Science, *Celestia*, a 3D application for exploring the Cosmos. Celestia enables students to move through the known Cosmos, from the local solar system to the remotest known galaxy. They can discover what is known about space objects, the relationship of those objects to near and far neighbors, and the science of an object's nature and existence. They learn the scale of the cosmos and discover the immense distances, speeds and times required by space travel. A nearly infinite variety of activities can be created for *Celestia*, and it can be augmented with additional space objects, their imagery, and their science information. *Celestia* is open-source, free to use, and supported by an active community of enthusiasts and educators. *Celestia* runs on mainstream, low cost PCs, under Apple, Linux, and Microsoft operating systems.

- For Earth Science, NASA Goddard Space Flight Center and the **LT Project Office** are developing a 3D Earth viewer able to take students from a near-Earth space view to one-meter surface resolution. Students can quickly and interactively navigate to any Earth location and vantage point. They can view space- or time-based data in the context of the Earth and its true and recent imagery. By selecting auxiliary data sets, students can view physical phenomena such as bathymetry and thermal characteristics, both static and dynamic. A virtually unlimited collection of Earth Science information can be made available simply by forming new data sets appropriately or by linking to public NASA data sites and feeds. Activities can be written for the out-of-

the-box viewer data or for new data. *Digital Earth Viewer* runs on mainstream, low cost PCs, under Apple, Linux, and Microsoft operating systems.

- Physical Research is supported in ExP initially through *NASA Virtual Lab*, an application under development at Kennedy Space Center. Targeted towards advanced high school students, college undergraduates, and technology school students, *Virtual Lab* provides interactive education on sophisticated instruments such as scanning electron microscopes and mass spectrometers. Activities focus on the art and technique of operating the instrument, or on the exploration and study of specimens. The instruments and the specimens are virtual. New specimens can be created without modifying the *Virtual Lab* application. New instruments can be programmed and incorporated into *Virtual Lab*. Activities can involve one or many instruments and one or many specimens. A community of scientists, engineers and educators creates the specimens, programs new instruments, and develops the activities. As required by ExP, *Virtual Lab* runs on all common computer operating systems and requires only mainstream personal computers and input devices. It is free to use and to extend.

ExP applications are required to be visually rich and engaging. They are ideally as appealing as a good video game, complete with 3D graphics and interaction, inviting backgrounds and environments, and interesting and compelling goals. Where appropriate they use sound, force feedback and visual immersion. As computer devices evolve and become inexpensive, ExP applications will incorporate haptic gloves, wands, and multi-screen displays. New technologies that come available will be applied.

ExP applications run at interactive rates on low-cost computers available in classrooms. (Defined in Section 4.) The applications are in most cases free, and in many cases open-source. Expense is not a barrier to obtaining and using any ExP application, either at school or at home.

While many ExP applications interact with the world-wide-web, they are mostly local applications, avoiding the limitations of web pages. They can take advantage of running locally to create an immersive experience and to achieve best performance and flexibility. They use the web and the internet appropriately for data gathering and interactive collaboration. They are downloaded and updated through the web.

NASA science, data and expertise is the source for ExP applications. Whether the applications are created within NASA or outside NASA, their content and activities reflect science that NASA is truly engaged in. Their data are almost always drawn from NASA sources. NASA scientists and educators are intimately involved in ExP projects.

To be part of ExP, an application must be general enough to support many activities. Educators must be able to create activities for an application independently of the application developers, and without writing software.

This independence includes the ability to add new data. An ExP application for learning about the Solar System, for example, has the ability to receive new or updated imagery,

geology information or planetary object data, obtained and incorporated by the educators developing the related curriculum. Tools to do this and perhaps some data formatting may be required, but software changes to the application are not. Eventually, applications such as *Celestia* may draw imagery and data directly from active NASA instruments, such as MOLA for Mars data.

Similarly, applications must be open and flexible enough to allow feature extension by the addition of independently developed software modules.

1.3 ExP Activities

ExP activities guide students towards learning specific concepts or details. They vary considerably in their content, level of detail and degree of direction. Some educators will give only general guidance in the activities they create; others will provide step-by-step instructions. The content of activities is the decision of the educators creating them.

Each ExP application has many activities associated with it. Activities are a requirement for application inclusion in ExP. The application authors or their education partners create the initial activities. The community around the application creates new activities and keeps the application's entire activity set up-to-date. Activity creation can go on indefinitely, as it will in a vibrant application community.

Activities are in many ways the primary deliverable of ExP. Applications are merely in service of them. It's the activities that guide student inquiry. It's the activities that capture the pedagogical intent of the educator.

ExP activities are free to use by anyone, including classroom teachers, museum docents and independent-study students.

Activities are in the form of electronic documents, instructions on web-pages, or perhaps programmed into an application itself, if the application has that ability. Their form is left to the discretion and resources of the educator.

Activity content, however, should follow ExP activity guidelines. These guidelines recommend that activities identify the educational standards they cover or adhere to, and that they be inquiry-based. They should lead students through an exploration rather than simply presenting facts or marching the student from one screen to the next. Activities help students learn more about the application so they can explore on their own, beyond the activity material.

Activities should contain separate instructions to educators and students indicating their target audience (e.g., K-12), their level of difficulty, and references that help a teacher or student assess whether the activity is appropriate for their needs.

ExP provides example activities that activity creators can emulate or draw ideas from. It also provides expert pedagogical advice for teaching through software applications like those in ExP. This advice is from distinguished educators commissioned specifically to

develop ExP activity guidance. ExP's example activities have been reviewed – and in many cases, created – by expert educators who evaluated them for pedagogy, appropriateness to the target audience, application to national science education standards, and quality. They are excellent material on which to base new activities.

1.4 ExP Software Components and Infrastructure

The applications in ExP are significant engineering achievements. Like any engineering endeavor, they benefit from using standardized technology and common components for popular features. Image processing, 3D graphics, and internet data access are just a few of the features used widely in engaging, modern applications. Many of these capabilities have existing, essentially off-the-shelf software solutions that can save application developers the time and expense of creating the capabilities themselves. ExP identifies these solutions and makes them easily available to ExP application developers.

Initial (year 2003) ExP software components serve the following needs:

- Internet data acquisition mechanisms to NASA Earth, planetary and space data
- Image processing
- 3D graphics and visualization
- Display and device management

Software solutions for all these needs exist now. Some of them are available within NASA and have their own software initiatives in progress, such as the federally sponsored *Geospatial One Stop*. ExP utilizes these existing solutions.

Other significant software engineering efforts are packaging, delivering and subsequently updating software. ExP and the Learning Technologies Office simplify these tasks by providing state-of-the-art tools for packaging and delivering ExP applications and updating them on the user's computer after installation. Additionally, ExP provides guidelines for delivering software and data in the form of a familiar ExP component.

Data acquisition and data transformation pose a large and difficult set of problems, as do the identification, storage and maintenance of data in many forms. ExP does not attempt to define ExP-specific solutions to data issues, but relies on standards already in-place or being formed. Data standards efforts are underway within NASA; ExP utilizes those efforts to determine solutions to advocate and provide to ExP material developers.

The goal of the software component and infrastructure portion of ExP is to make ExP application development simpler, and to make it more timely with respect to both time-to-delivery and state-of-the-art features and device support.

Besides being selected for their functionality, ExP software components are selected for their ability to enable high-technology features on mainstream computers. The target platforms for all ExP applications are **graphics-enhanced personal computer**s affordable to public classrooms of K-12 schools. Because the ExP staff and community continually research, evaluate and recommend software that brings out the best in these

computers, ExP applications that use this software automatically run optimally on these devices.

NASA also uses ExP as a platform to expose timely new software capabilities with potential for widespread use in science education. One example under development is sonification of time-series data, primarily to aid interaction with data by blind persons, but potentially advantageous to all. By developing this NASA technology as software componentry, the capability is easily adopted by many applications.

ExP components are judged on their openness. Open-source software is preferred; it allows application developers to enhance or repair the software to meet their specific needs. Actively maintained open-source software has the advantage of fast repair and enhancement turn-around, as well as a responsive community of experts to offer help and advice.

As with ExP applications and activities, ExP componentry and infrastructure evolve and grow with need and opportunity. Initial components and services are those identified by the first ExP community. Additions, updates and replacements occur as needs are identified by the growing community and as technology becomes available. New technology will be commissioned or adopted when requirements and opportunities arise.

1.4.1 Infrastructure Services

An additional set of services is necessary to support application and activity publication and delivery. These include a site for obtaining ExP materials and ExP integration into educational material catalogs.

The Learning Technologies Project Office maintains a public web site for application description and download. Current versions of ExP applications are always available there for anonymous download. The site is the also repository for post-installation application updates.

The Earth Science Education Digital Library (ESEDL) developed and supported at NASA's Goddard Space Flight Center is the catalog of choice for registering ExP materials. This library interfaces with the NSF-funded Digital Library for Earth Science Education (DLESE) and the National Science Digital Library (NSDL), also NSF-funded. By registering materials with ESEDL, they are automatically made visible to users of these other libraries, and of a wider network of education material catalogs. All ExP materials are registered with ESEDL when available.

As ExP and LT experience develops, ExP will provide tools to help material creators register their work with ESEDL and other libraries. This need is not being addressed in the first year, but it is an important aspect of ExP and will be addressed subsequently.

2 ExP Requirement Details

An itemized summary of the ExP requirements are listed in this section. These more detailed descriptions echo the descriptive presentation above, but in some cases provide

additional specifics. As mentioned in the Preface, ExP is constantly evolving, therefore the set of requirements listed here will change and grow.

2.1 Application Requirements

1. Applications must have an educational, inquiry-based focus.

2. Applications provide an open setting that students can freely explore.

3. ExP applications must be sensorily rich and engaging. Ideally, they are as appealing as a good video game, complete with 3D graphics and interaction, inviting backgrounds and environments, and interesting and compelling goals. Where appropriate they use sound, sensory feedback, and visual immersion (multiple display surfaces).

4. Applications must reflect science or missions that NASA is truly engaged in. While applications need not confine themselves to topics of the five NASA enterprises, they must address at least one of those enterprises or the skills that support them (e.g., Mathematics, Physiology, Astronomy).

5. The potential to build a community of users, educators and developers around the application must exist, or such a community must already exist.

6. Applications must run at interactive rates on low-cost computers available to students. They must operate on personal-computer hardware and operating systems affordable to classrooms. (Defined in Section 4.) They should run under Microsoft, Linux and Apple operating systems.

7. Applications must be free to use, or require at most a single, low-cost license for unlimited site or home usage per organization – school, school district, museum, family, etc. Expense must not be a barrier to obtaining and using any ExP application, either at school or at home.

8. Applications must be sufficiently general to support many activities. They must have at least ten high quality activities available upon initial release into ExP.

9. Educators must be able to create lessons for an application independently of the application developers, and without writing software.

10. It must be possible to add enriching or updated source or display data to the application without reprogramming or otherwise modifying the application's source code, and without having to create software extensions to the application. At most, minor and simple scripting may be required for dynamic extensions.

11. Applications should be sufficiently open and flexible to allow feature extension by the addition of independently developed software modules or extensions. Their source code and supporting material should be freely available.

12. ExP applications must determine their compliance with "Section 508" accessibility requirements. It is yet to be determined whether all ExP applications must conform fully to these requirements, although they should attempt to do so.

2.2 Activity Requirements

1. Activities should be inquiry-based, leading the student through exploration. They must allow the students to control their progression through the lesson.

2. Activities must be freely accessible and free to use. They must exist in a format readily accessible by students in public school classrooms.

3. Activities must be professional quality and comprehensive relative to their goals.

4. Activities should identify the relevant government standards they support, and the pedagogical methods or theories they use.

5. Activities should contain a means to evaluate or indicate student learning of the activity material. E.g., worksheets, quizzes, pre- and post-activity evaluations.

6. Activities must be based on one or more ExP applications.

7. Activities should target all or a subset of grades K-12.

2.3 Software Component and Infrastructure Requirements

1. ExP software components must support the needs of ExP software applications or the process of building activities for those applications.

2. The potential to build a community of users, educators and developers around the components must exist, or such a community must already exist.

3. Components must be consistent with or in support of application requirements to run at interactive rates on low-cost graphics-enabled personal computers available to students in classrooms. Components must operate on computer hardware and operating systems available in classrooms, including, at a minimum, personal computers running Microsoft, Linux or Apple operating systems.

4. Components must be free to use, or require at most a single, low-cost license for unlimited site or home usage per organization – school, school district, museum, family, etc. Expense must not be a barrier to obtaining and using any ExP application, either at school or at home.

5. Components should be sufficiently open and flexible to allow extension by independent software developers. Their source code and supporting material should be freely available.

6. Components must be well documented for their target audience. For software components, the target audience is typically software developers. Educators are typically the target audience for lesson-building tools.

7. The LT Project Office provides component consulting and guidance to developers and lesson builders. Application authors or sponsors, and lesson builders must supply any necessary guidance and consulting to application and lesson users.

8. The LT Project Office provides guidance and direct support for packaging, releasing and updating ExP applications and components. The LT Project Office manages and maintains the ExP distribution site and materials.

9. The LT Project Office, in conjunction with others in the NASA community, continually evaluates candidate entrants to ExP, and selects the entrants.

10. The LT Project Office manages and maintains any software that is not part of a separate on-line community.

11. The LT Project Office purchases any necessary licenses for software infrastructure applications or support, e.g. commercial packaging and distribution utilities.

3 Legal Considerations

The legal considerations, requirements and constraints for software created or commissioned by NASA are being determined in consultation with NASA legal staff. As of the "Last updated" date of this document, the determinations have not yet been made. ExP requirements and distribution details may change once these determinations have been made.

4 Definitions, Acronyms, Abbreviations

Activity	A series of steps and instructions for a student carrying out a guided exploration. May be in the form of a document separate from the ExP application, or any other easily usable form. Ideally contains questions for the student to answer, advice on achieving proficiency with the ExP application, and pre- and post-tests.
ExP	NASA Learning Technologies **Ex**periential **P**latform
LT Project Office	NASA Learning Technologies Project Office
Middleware	Software used by applications internally. Seldom visible to the user of the application, this software aids the application developer in creation and execution of the application.
May	Indicates a requirement that is desirable to achieve, but not necessary.
Must	Indicates a "hard" requirement that is necessary to meet completely.
Open-source	Software whose source code and development materials are public, visible and accessible. The software is free to use and

	extend. It typically has an open, on-line community supporting it. Several licensing schemes are used, but the open-source intent is to make software available and unencumbered for non-commercial use.
Should	Indicates a requirement that is strongly encouraged, and relaxed only with special consideration.
Graphics-enhanced personal computer	A x86 or Apple desktop, deskside, or laptop computer running at 1 GHz, with 256 MB of RAM and a 3D graphics card with 32 MB of graphics memory.

5 Acknowledgements

- Pictures are by Fridger Schrempp. Other pictures of his are available at http://bruckner.homelinux.net/celestia_gallery.html .
- *Celestia* was written and contributed to open-source by Chris Laurel (claurel@shatters.net). We are very appreciative of his willingness to include *Celestia* in ExP. More information on *Celestia* is at http://ennui.shatters.net/celestia/.
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- Don Burns of Andes Engineering prototyped a "cheap machine" version of his *Blue Marble Viewer* earth-visualization application. He convinced us, and many others, that high quality and highly interactive 3D graphics applications could now run on low-cost, mainstream personal computers.